Hybrid Energy Systems

Utah Governor's Energy Development Summit

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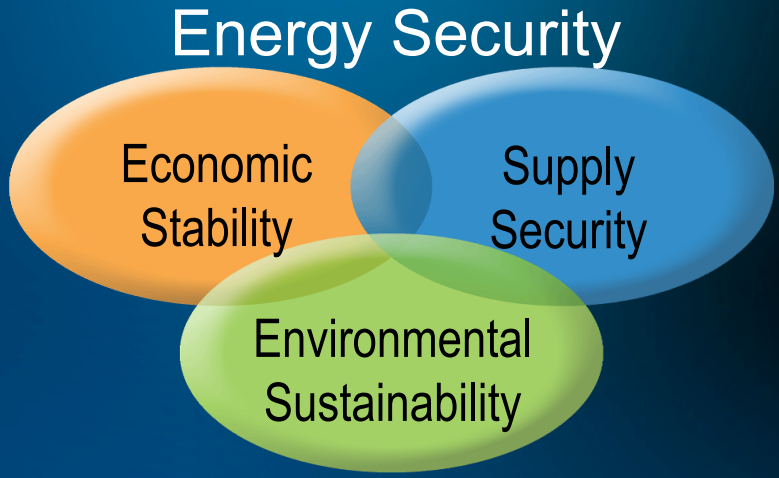
Richard D. Boardman

Department Manager
Energy Systems Integration

www.inl.gov

Idaho National Laboratory



The world will be powered by many energy sources…

Traditional Energy

- Coal
- Gas turbines
- Steam turbines
- Gas engines
- Diesel engines
- Nuclear

Renewable Energy

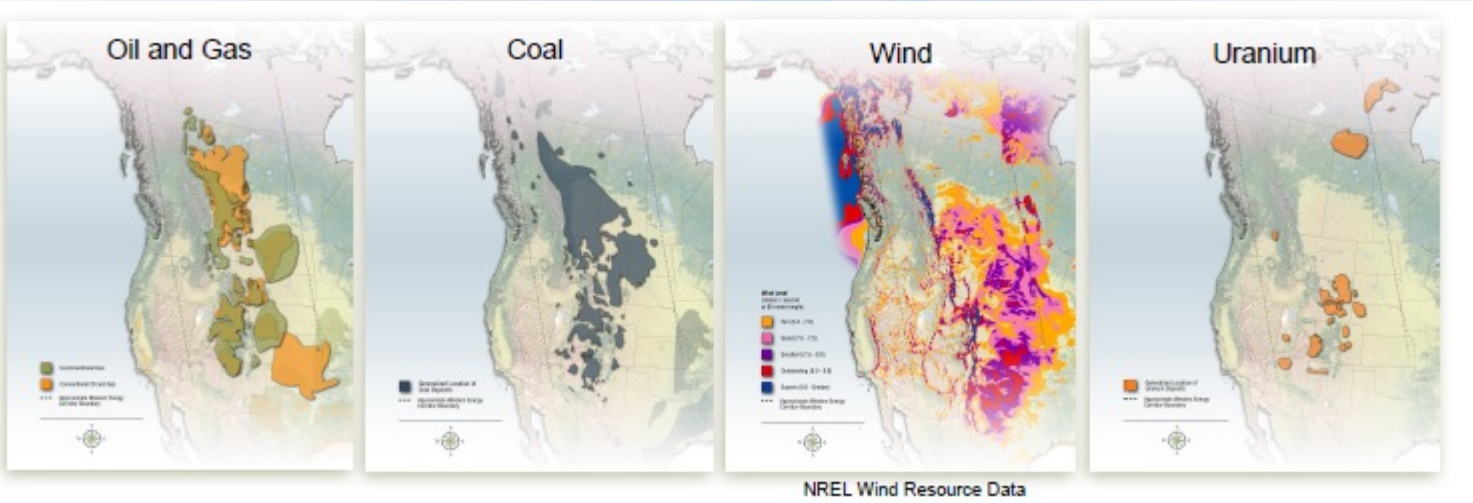
- Solar Thermal
- PV
- Geothermal
- Wind
- Biomass
- Waste heat recovery
- Hydro

Energy Storage

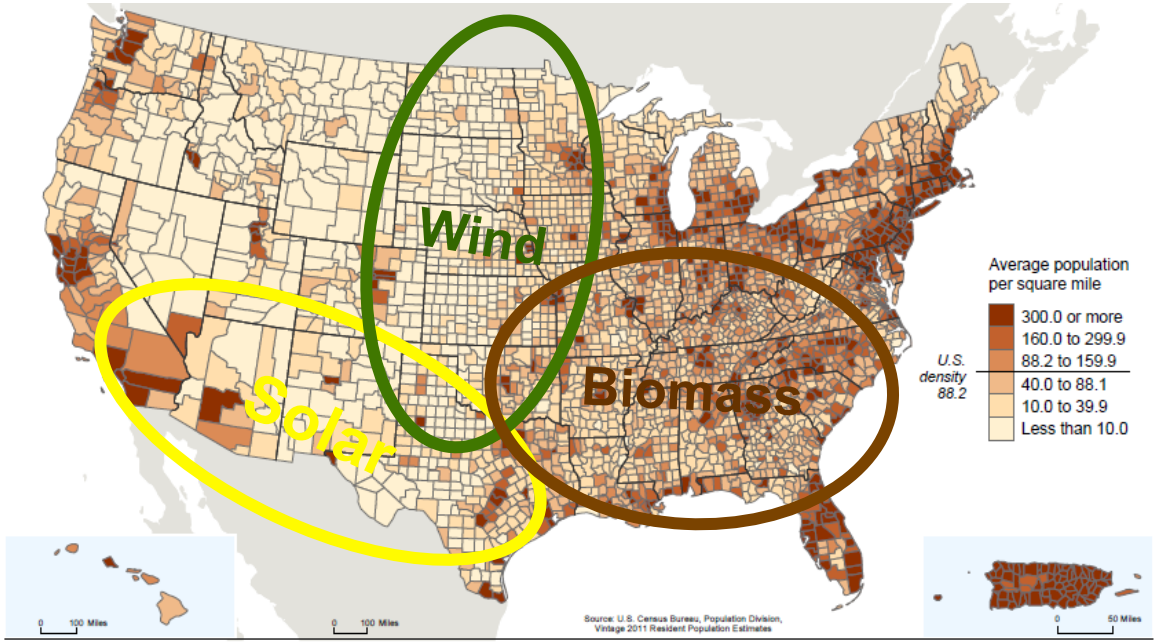
- Batteries
- Compressed air
- Pumped hydro
- Chemical fuels – H_2, CH_4
- Heat

…but are there special COMBINATIONS or HYBRIDIZATIONS that are particularly attractive?

Western Energy



NREL Wind Resource Data

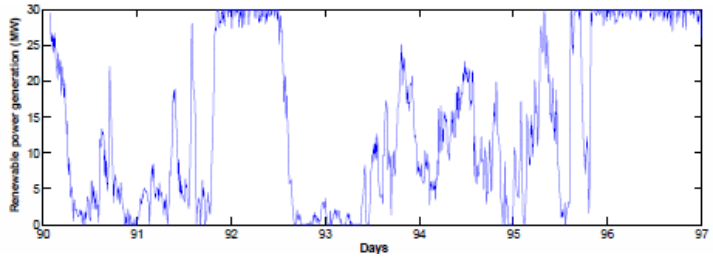


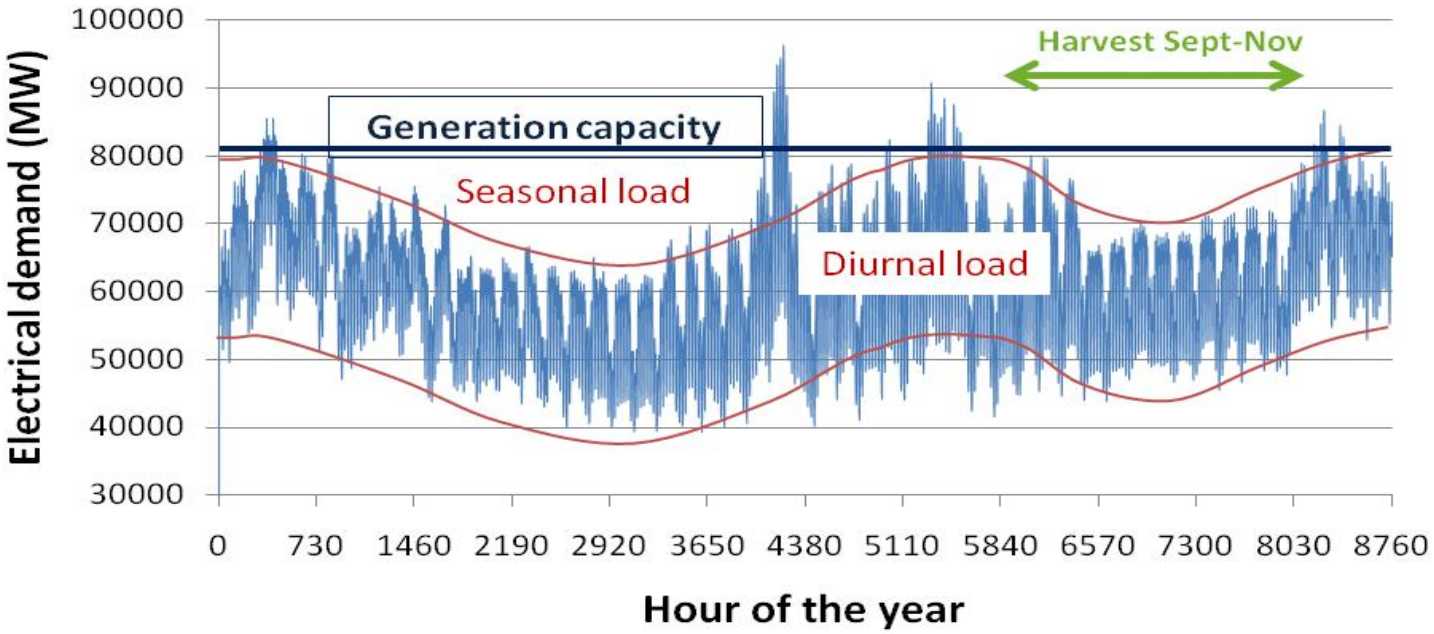
Renewable energy vs the population

Power dynamics create Hybrid System Opportunities

The Problem:

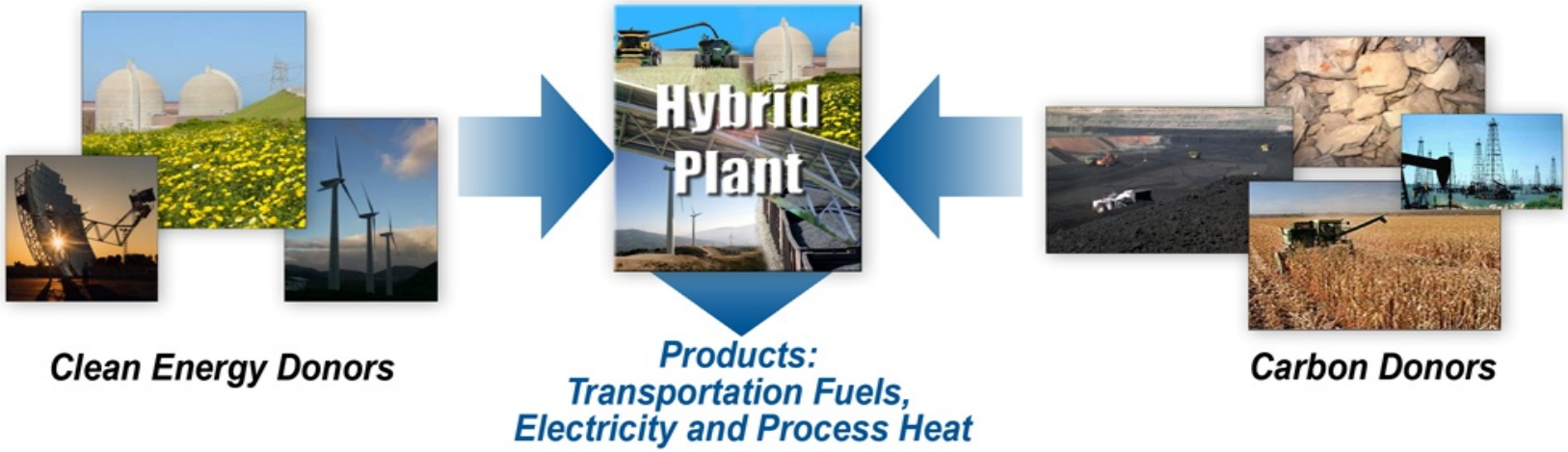
- ✓ Intermediate and peaking generation is underutilized
- ✓ Fossil fuel power generates GHG emissions
- ✓ New nuclear reactors are expensive
- ✓ Renewable sources are variable and random





- ✓ Excess diurnal capacity is available year round
- ✓ Excess seasonal variation is also available for other work

Summary



Hybrid Energy Systems integrate energy conversion processes to optimize energy management, reliability, security, and sustainability

- ✓ Facilitate effective integration of renewable energy, overcoming the challenges of intermittency and transmission constraints
- ✓ Open markets for nuclear energy beyond only a percentage of base load power
- ✓ Promote better usage of carbon sources, including natural gas and biomass, for the production of transportation fuels while reducing GHG environmental impact
- ✓ Support smooth integration and enhanced efficiency of conversion of available energy resources into infrastructure compatible products

Co-Gen? Hybrid? What's the Difference?

Thermodynamic Efficiencies

Reactor as "Heat Machine" For General Purposes

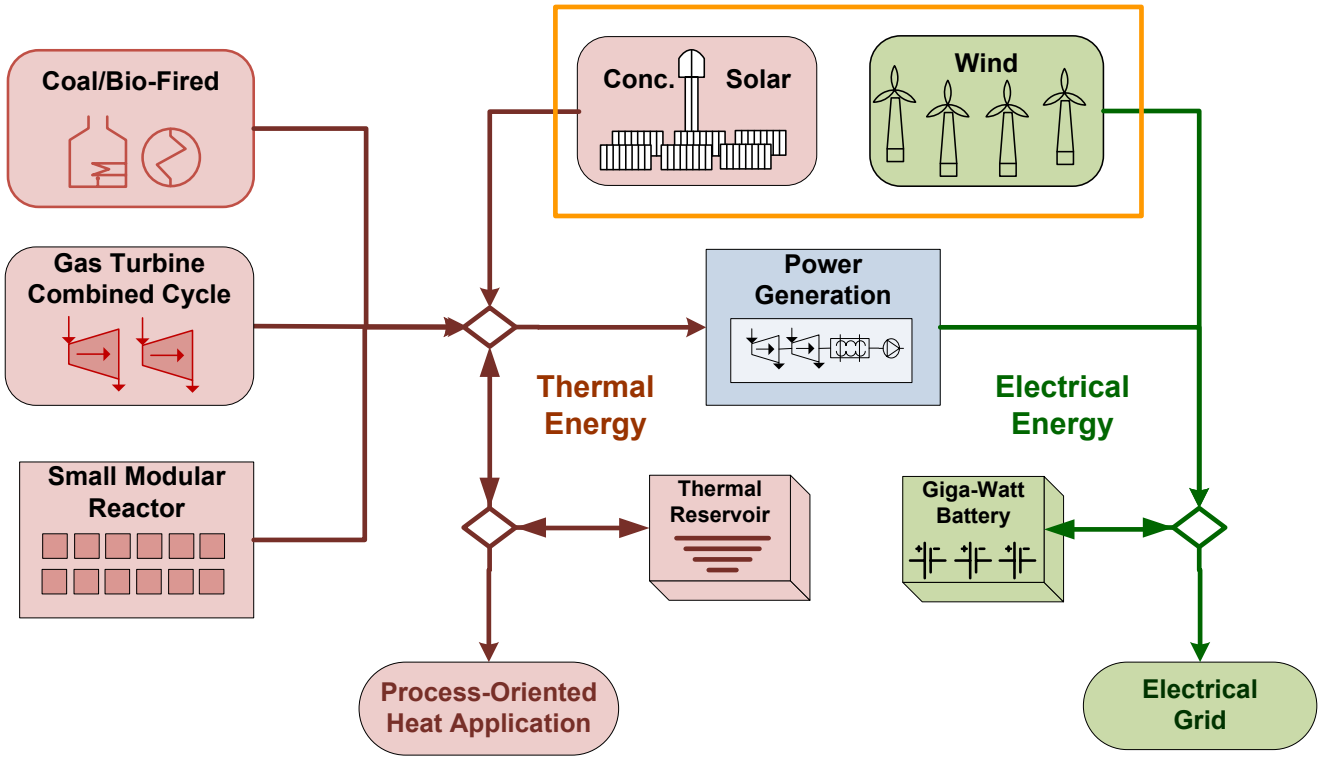
Economic Efficiencies: Capacity Factor and Time-of-Use Value

Integrated Energy System to Make Synthetic Fuels in Quantity

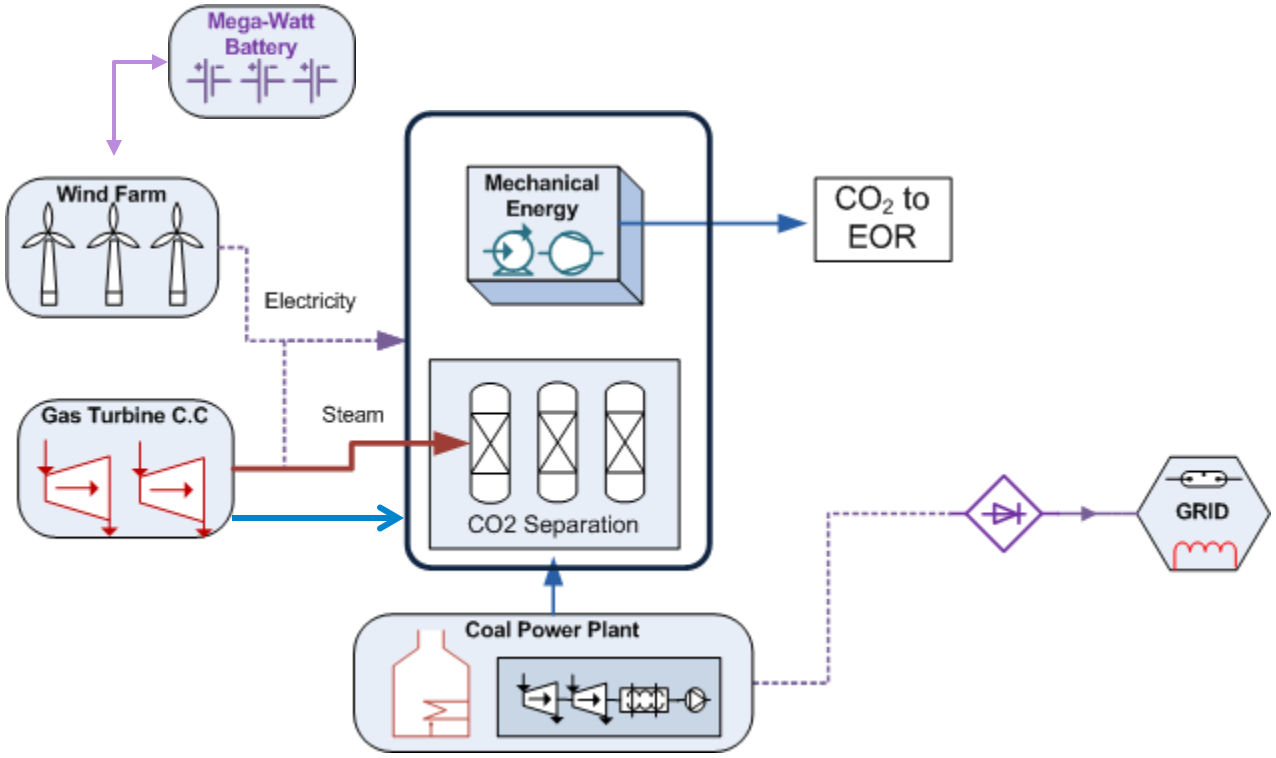
Co-Generation

Process Heat Applications

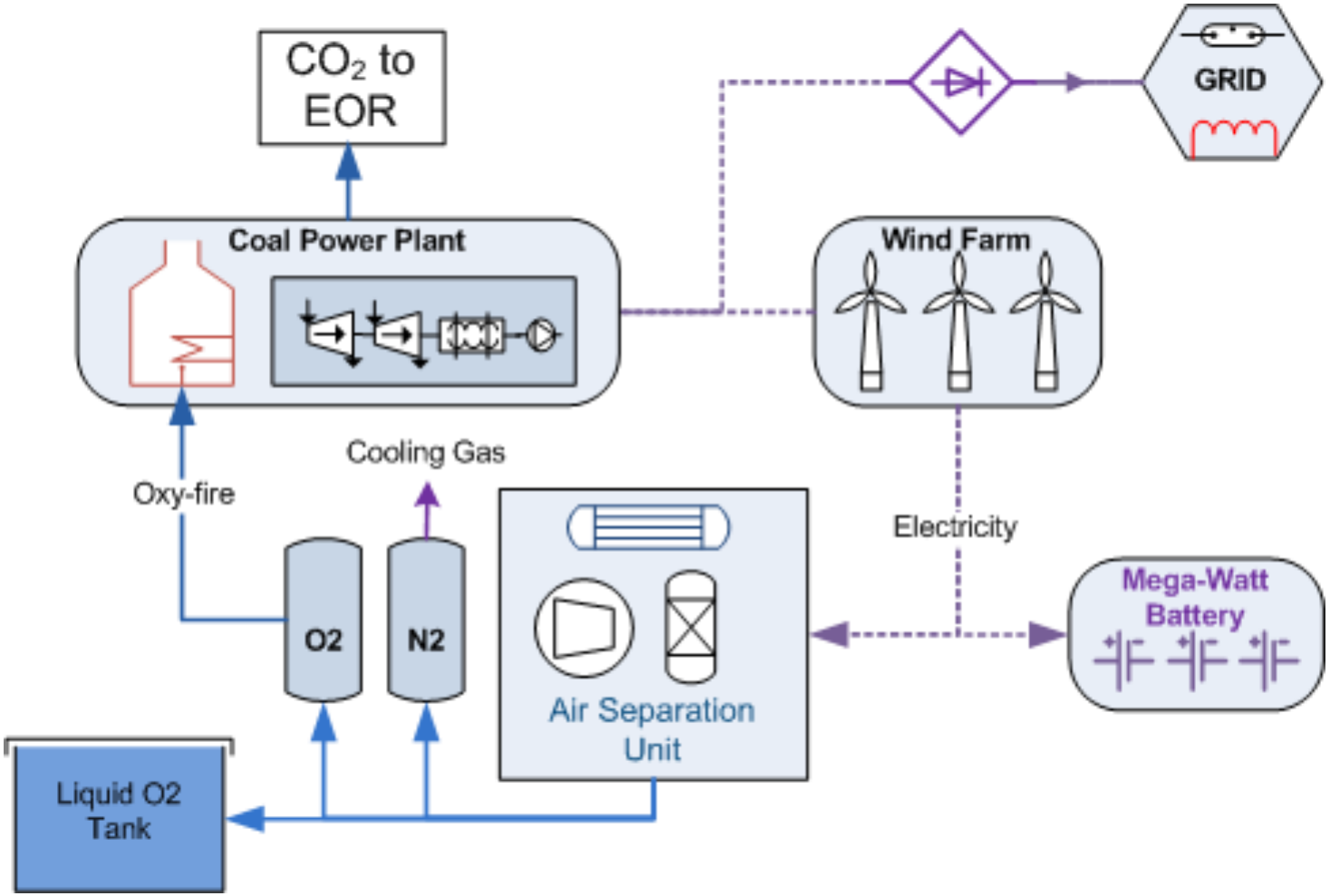
Hybrid Systems



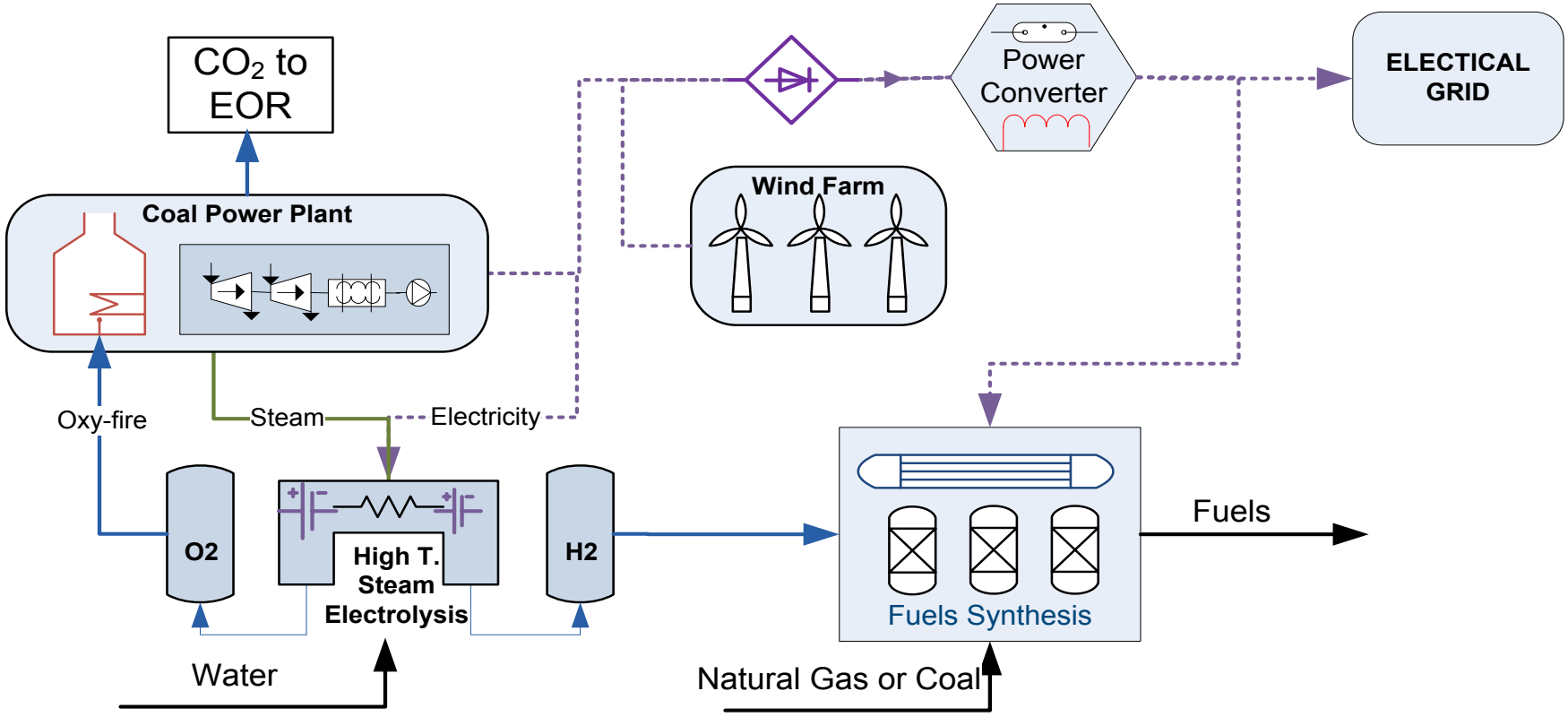
CO_2 Management – Flue Gas Scrubbing



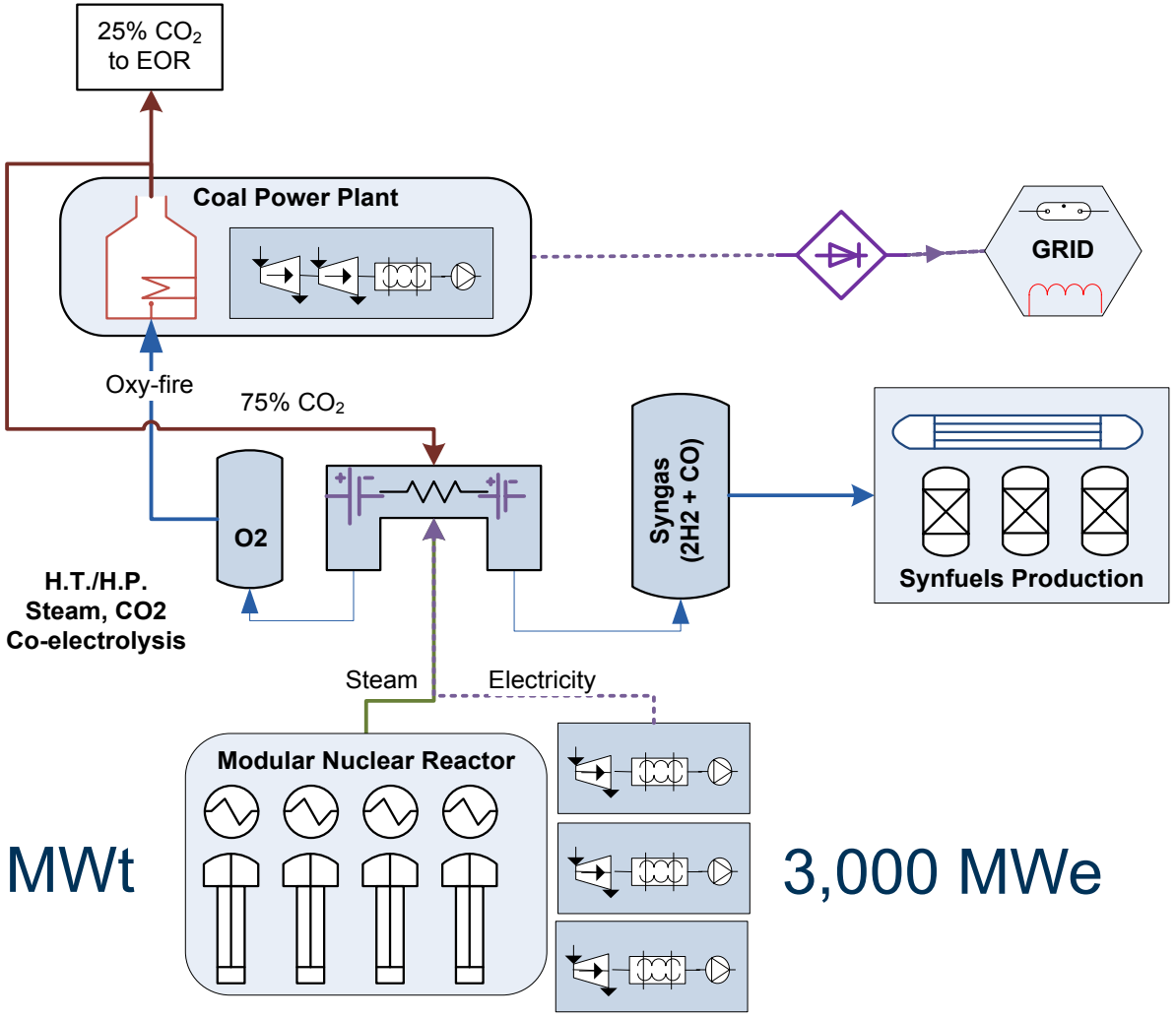
WIND TO CO_2


CO_2 to EOR
GRID
Coal Power Plant
Wind Farm
Cooling Gas
Oxy-fire
Electricity
O2
N2
Air Separation Unit
Mega-Watt Battery
Liquid O2 Tank

Hybrid Systems Power & Fuels Production



Retrofit PC Plant: "Burn Coal Twice"



~11,000 ton coal/day

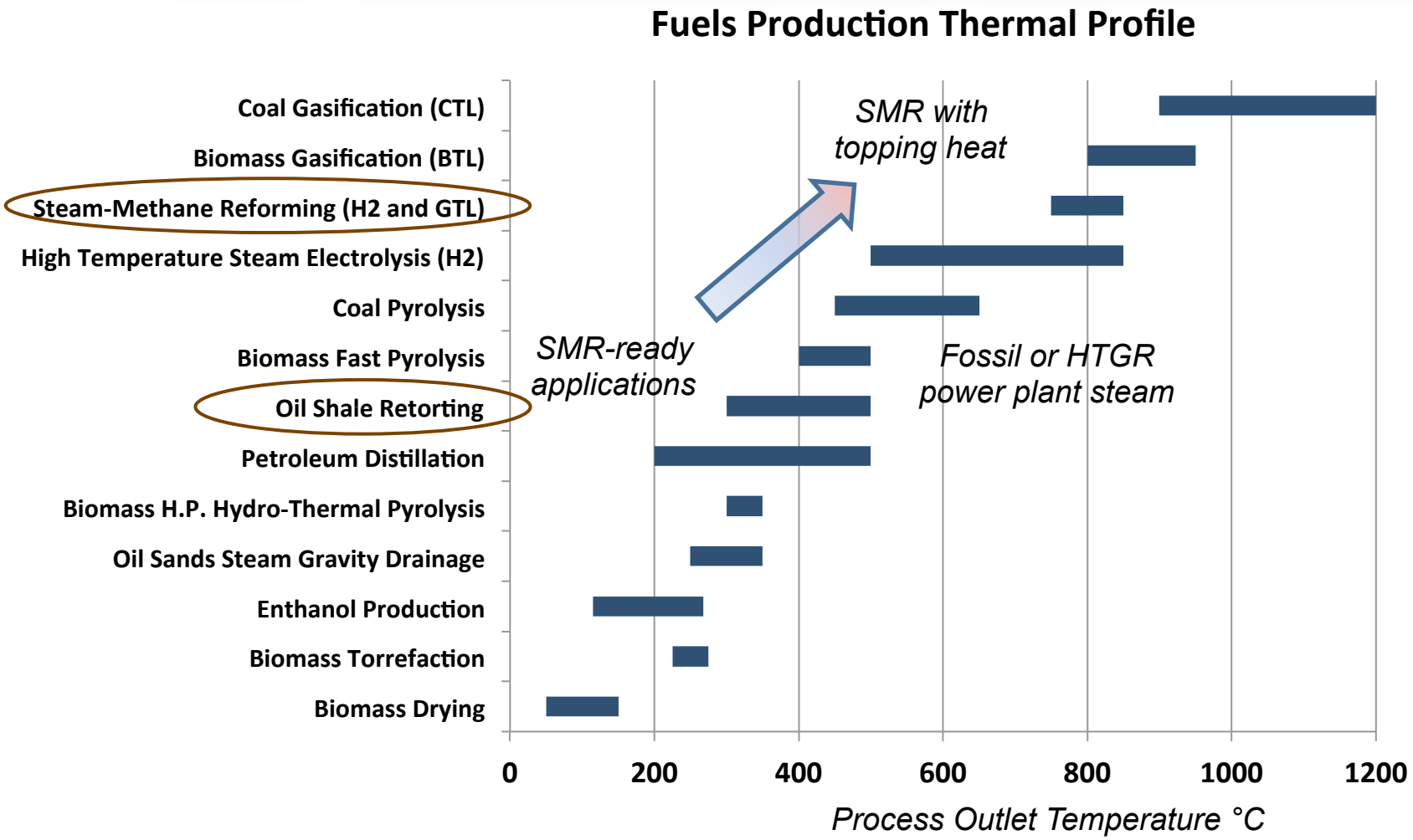
750 MWe

65,000 bbl/day

2,500 MWt

3,000 MWe

Liquid Fuels Alternatives



Load-Following SMR NHES-
Turning Natural Gas into Gasoline

Light water SMR

530 MW heat

Steam turbine generators

Max Power
170 MW electricity**

Load-following intermediate power

Natural gas $9/ MMBtu

fuel*

Steam generation

steam

Methane reforming

carbon

Methanol synthesis

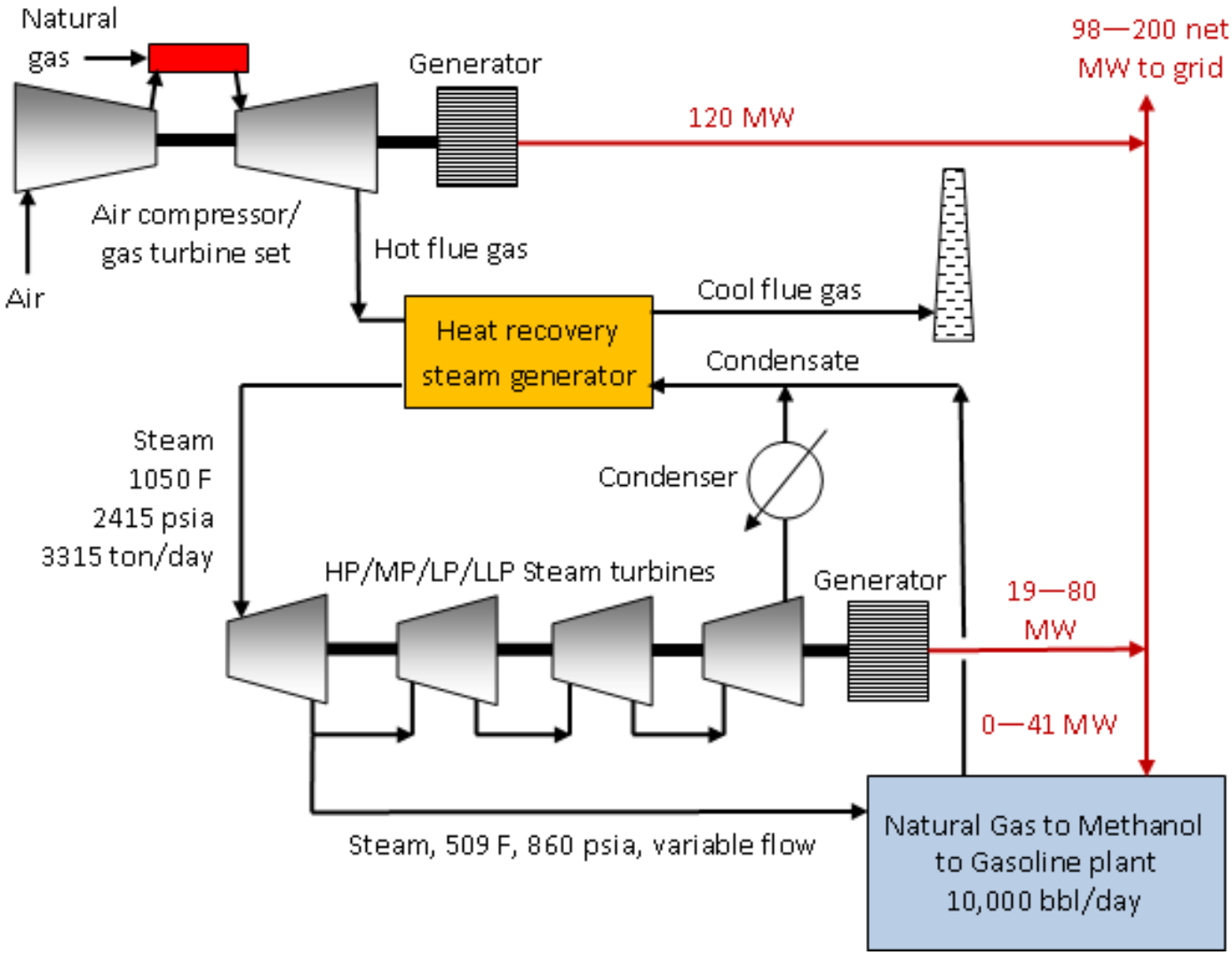
12,500 tonnes/day**
(~49,000 bbl oil equiv per day)

Synfuel: gasoline, biodiesel, or DME

- ✓Annual return on investment - 12.7% for HES versus 9.9% for non-hybrid
- ✓ 90% reduction in natural gas used for energy inputs
- ✓Based on representative power demand data for Midwest U.S.

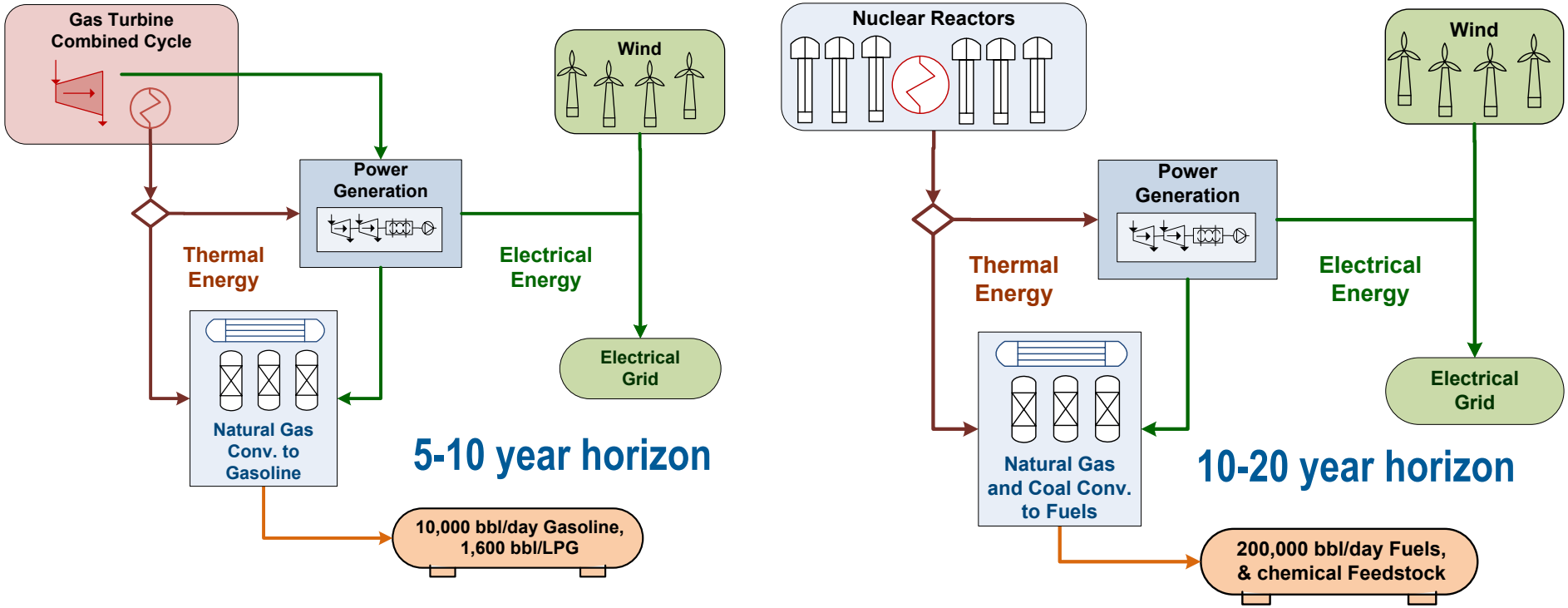
Source: Cherry, et al., Energy Env. Sci. 2012, **5**, 5489

Natural-Gas Combined Cycle Hybrid



Energy Systems Hyrbidization

Ensure reliable and affordable sources of energy by diversifying the technologies for generating power by system integration



Increased use of wind power generation may require hybrid energy system concepts to provide enhanced dynamic grid control

Idaho National Laboratory

INL/EXT-12-27249

Preliminary Feasibility of Value-Added Products from Cogeneration and Hybrid Energy Systems in Wyoming

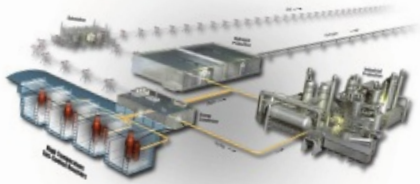
November 2012

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

INL/EXT-12-26732

Energy Development Opportunities for Wyoming

November 2012



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Wyoming Business Council

NGNP Industry Alliance